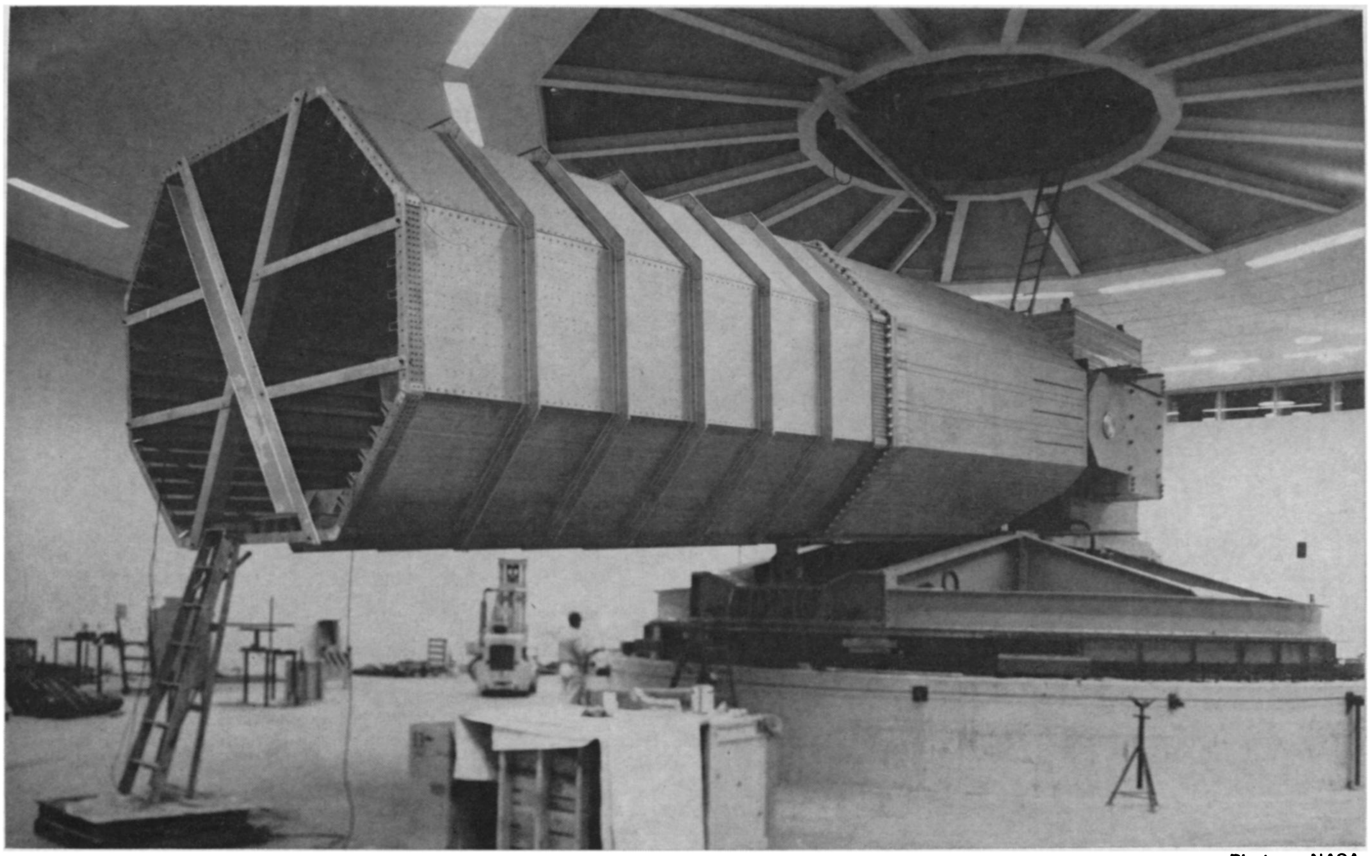


Photos: NASA

The Ames centrifuge, carrying an instrumented capsule, will study the physiological changes in animals and humans.

AEROSPACE

Studying the effects of gravity

The centrifuge at NASA's Ames Research Center will produce up to 50 g's to explore effects of gravity changes

by Everly Driscoll

The force of earth's gravity, universal and inescapable, is unique among the forces influencing terrestrial life. Yet very little is known about its effect on biological systems. For hundreds of years, scientists have speculated about the physiological changes which might result from extensive periods under increased or decreased gravity, but little experimentation was either possible or necessary until men began to fly. Even then, the effects of increased g loads on pilots were often treated symptomatically without much understanding of the nature of the effects themselves.

Within the past decade however, the prospects of travel to other planets, where gravity could be several times that of the earth, and the plans for extended space-station living under conditions of zero gravity, have made research in gravity effects more urgent.

The apparently reversible effects of weightlessness on Gemini and Apollo astronauts and Soyuz cosmonauts—stability problems, transient blood abnormalities, increased white-cell and decreased red-cell counts, abnormal red-cell proteins and bone-calcium and muscle-nitrogen deficiencies—provided some data. Despite this input, however, and additional bits and pieces of insight gained from animals and plants exposed to weightlessness for varying periods of time, space-flight doctors are still looking for more complete information.

They have felt the need for some kind of earth-bound simulator that would permit them to draw some general conclusions about the real-time effects on living things of changes in gravity.

Although true weightlessness cannot be simulated for long periods on earth, increased gravity levels can be simulated in centrifuges. The Navy and Air Force have been using such instruments for years to explore pilot ability to function under the increased g loads which occur in flight. The National Aeronautics and Space Administration uses large centrifuges at the Manned Spacecraft Center in Houston, in which astronauts train for the six to seven g's of launch and reentry into the earth's atmosphere.

Such training and post-exposure examinations have led to the development of protective gear and an understanding of some momentary effects. But scientists would still like to know in real time exactly what is happening to body functions and systems during exposure to abnormal gravity. For a study of the effects of increased g loads scientists use a variety of centrifuges. And by the beginning of 1971, engineers at NASA's Ames Research Center, Moffett Field, Calif., hope to have in operation a centrifuge capable of taking animals up to 50 g.

But for zero gravity, where much of the concern is focused now, there is not much to be done. Zero gravity cannot be effectively simulated for animal research.

The next best thing, short of a space laboratory, is to extrapolate: Accustom animals to high gravity and then take them down to normal earth gravity as if they were going from normal g to zero. According to Dr. Jiro Oyama, chief of the physiology branch at Ames, this is one way of simulating the physiological effects of zero gravity.

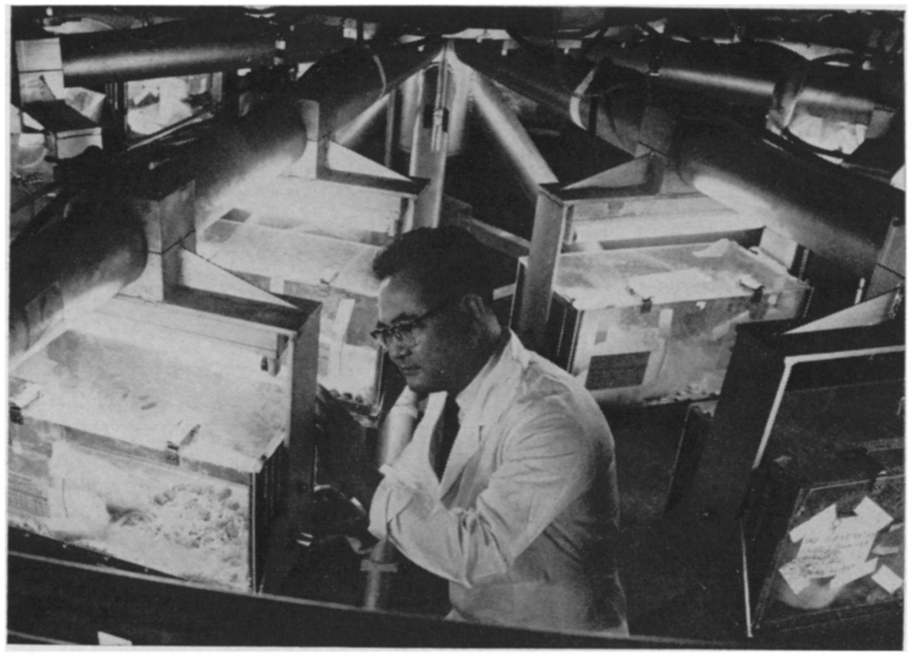
Using a 52-foot-diameter animal centrifuge which can run constantly for years with only intermittent stops, Dr. Oyama has raised entire generations of rats and mice under increased gravity. From these experiments he has found that the time required for animals to adapt to increased g is less for young animals than for mature ones; that smaller animals such as mice are more capable of reproducing when exposed to increasing g than the larger ones; that a rat's life span may be increased —some have lived as long as four years on the centrifuge—and that the increased g does not appear harmful to either species when the exposure is extended over prolonged periods of time.

Dr. Oyama is now extending his studies to larger animals.

During the past year, pedigreed dogs have been exposed in his centrifuge to gravity more than twice that of the earth's. Although the dogs did not show the initial body temperature variations that occurred temporarily in rats, they did show a sex-linked reaction differential: The male dogs tolerated the increase better than the females and were able to gain weight.

The most significant change, however, was in the bone and heart masses of the dogs. These masses increased as much as 25 to 30 percent after three months on the centrifuge. After the dogs were removed for one month, they still showed an increase in bone and heart mass, but the increase was less than that found in dogs right off the centrifuge. The experiment has been repeated several times with the same results. More research, however, is still in process. One question to determine is whether the bone and heart mass would ever return to the sizes of the dogs that had not been centrifuged.

"What we are trying to do," says Dr. Oyama, "is examine quantitative increases or decreases in biological functions. We hope to get some basic relationships established between a wide variety of physiological functions as related to changes in gravity in order to provide us with predictive effects of long-term low gravity exposures." Although the study with the dogs provides only basic information, Dr. Oyama feels that the results do have relevance to possible weightlessness effects on man. Astronauts have experienced a bone density loss after space flights, due most likely to calcium loss, perhaps the obverse of the effects of excessive gravity on the dog's skeletal structure.



Oyama: Raising generations of rats and mice under increased gravity.

The detailed work on extrapolation to zero g, however, is still to be done.

"We just don't know that much about the effects of gravity or the peculiarities in humans for which gravity might be responsible," says Dr. Joseph F. Saunders, chief of environmental biology of NASA's Office of Space Science and Applications. "Although it is not likely that the effects of going from two or more g to one g can be extrapolated precisely to those effects from one to zero g," he says, "it is quite possible that we may be able to predict certain metabolic changes based on our studies with high g effects."

Officials responsible for manned space flights, on the other hand, are less interested in the centrifuge data. They prefer to extrapolate from the effects of one manned flight to another: physiological results of weightlessness from the 14-day Gemini flights, for instance, are being used to extrapolate what will probably occur in the 28-day Skylab flights planned for 1972.

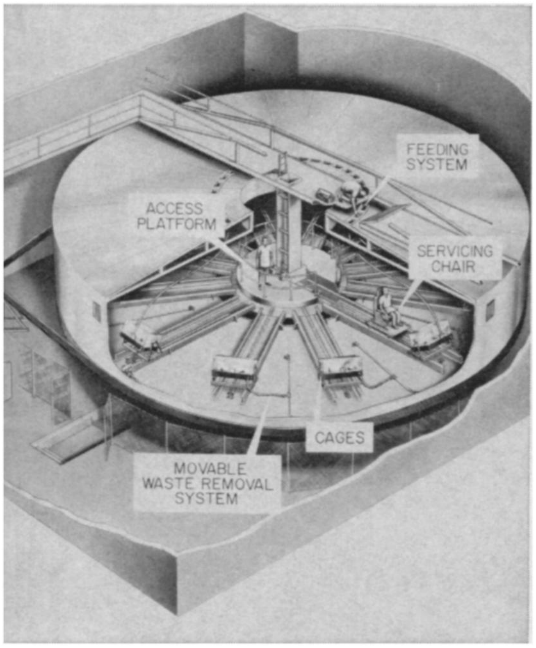
Some of the questions may begin to be answered in January when the 50-g centrifuge goes into operation at Ames. This 10-year-old, $9 million project will permit scientists to use standard medical laboratory equipment for real-time observations of physiological changes in both animals and humans. The centrifuge will be able to carry a 2,000-pound Apollo-type capsule, including crew and equipment, up to 20 times the force of earth's gravity; it will carry animals and equipment up to 50 g.

Using the instrument-equipped centrifuge, scientists will be able to measure brain waves, breathing processes and heart and visual responses to increased gravity at the time they are being affected. "If we can understand what is bothering the pilot above 12 g," explains George Rathert, chief of the simulation sciences division at Ames, "we can either develop equipment, or modify the control tasks he has to do."

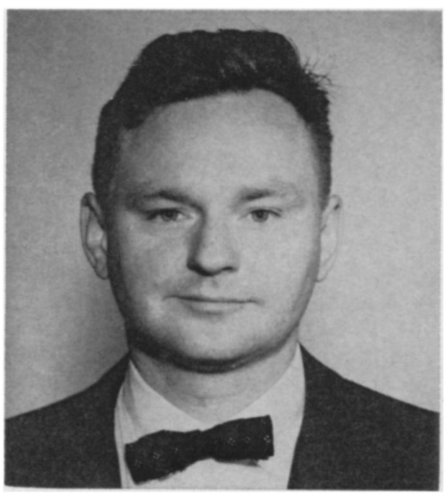
The Ames officials believe the 50-g centrifuge will answer their needs for some time to come. "This project represents significant advances beyond existing equipment," says Rathert. "Its combination of speed and size has not been duplicated anywhere that we are aware of."

Most centrifuges are designed as closed-loop systems which drive the cab in a preset pattern. But in the new Ames machine, the motion systems are all designed to respond to the control input from a human pilot. Other innovations include the use of the hydrostatic bearing to support the weight and react to the forces developed as the gimbals are used. It will also carry a complete environmental system capable of simulating airplane operations up to an altitude of 100,000 feet.

The 50-foot arm of the machine is



Centrifuge: 52-foot four-year home.



Rathert: Studying what bothers pilots.

run by a 230-ton dc motor; it can produce 5.58 million foot-pounds of torque, and has a peak horsepower capability of 18,800. The speed of rotation on the 35-foot-diameter bearing is greater than 60 miles per hour.

When the centrifuge was first planned, engineers wanted to devise a machine that would produce the most in flight simulation, except for weightlessness, that would ever conceivably be needed for flights to Jupiter or Mars and back—the last word in centrifuges.

The 50-g machine may give them everything they want. But whether they will be able to carry Oyama's work forward, extrapolating back to zero g, and whether even if they do they can sell their results to the manned space flight people, remain the kind of questions NASA usually regards as "open." □